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RINSE:

A digitally implemented flywheel sync regenerator for improved video synchroniser performance

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RINSE: A DIGITALLY IMPLEMENTED FLYWHEEL SYNC REGENERATOR FOR IMPROVED VIDEO SYNCHRONISER PERFORMANCE

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Summary

Microwave links are widely used at live outside broadcast events for carrying video signals from mobile cameras such as those carried on the shoulder or fitted to vehicles. A digital frame store synchroniser is required when using a remote radio-camera and this has caused additional problems with variable quality signals. During moments of weak signal strength when threshold noise appears in the picture, a video synchroniser may lose synchronisation and produce an unnatural freeze-frame effect.

A new device called RINSE — Regeneration and Insertion of New Sync Equipment — is described, which replaces the old variable quality syncs with 'flywheel' regenerated syncs. When connected between the microwave receiver and the synchroniser, it cleans up the syncs and allows the synchroniser to pass the video without the freeze frame artefacts which would further degrade the picture. By operating the synchroniser with an external sync input from RINSE, it will carry **any** *video signal transparently for a short time irrespective of the noise level.*

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1. INTRODUCTION

Microwave links are widely used at live Outside Broadcast (OB) events for carrying video signals from mobile or portable television cameras[1] back to the vision mixer. These cameras may be either carried on the shoulder as a single operator radio-camera or fixed to a vehicle such as a motorcycle, boat, helicopter, or Formula 1 car, and offer an exciting viewpoint.

In the case of a one-man radio-camera, the transmitted signal is simply received by a dish at a fixed site, which is usually situated a few hundred metres away at the most. Vehicle mounted cameras, on the other hand, generally operate over much larger areas, so an intermediate mobile receiving site, such as a helicopter, is often used to relay the signal to a second receiving site on the ground. Either situation can lead to a degradation of the video signal and this causes a particular problem when the video is fed through a video synchroniser. In the case of the helicopter mid-point link, this introduces a double hop with twice the likelihood of a signal dropout.

Degradation of the video signal carried by a mobile link can be caused by signal loss; this may occur for many basic reasons, such as: momentary path blocking, mis-panning of the receiving dish or the banking of a link helicopter. In built-up areas, flat-fading can also be caused by multipath propagation. Much has been done to counteract these problems by the use of novel antenna designs and sophisticated directional antenna systems; but, however inventive the technology of the RF link, there will be times when it is unable to provide the required signal level at the receiver.

Picture impairment due to excessive noise is often very short-lived and a relatively minor problem when viewed on a picture monitor connected directly to the receiver output; but it is compounded by the use of the digital frame store synchroniser, which will always be used with a radio-linked camera.

Most synchronisers have been designed to work with studio quality signals and fail dramatically when presented with the variable-quality signal often experienced at live OBs. They can turn very minor picture disturbances (which last for only a few lines or less) into full frame effects. The cause of this picture break-up is usually distortion of the sync pulses, either due to noise or multipath effects.

RINSE — Regeneration and Insertion of New Sync Equipment — is a compact device for replacing the variable quality syncs of a radio-camera signal with precise noise-free syncs generated from an on-board master oscillator. Rather than using a fixed frequency reference, the oscillator used in RINSE is tuned to match the frequency of the incoming video signal. Its novel design enables accurate syncs to be generated, even in the presence of severe noise and multipath degradation lasting several seconds.

This Report discusses the problems of using frame store synchronisers with radio-linked cameras and describes how RINSE can significantly improve the performance of mobile microwave links.

2. FRAME STORE SYNCHRONISERS

Pictures from remote sources, such as radio-cameras, are only of any use if they are synchronised to the local or 'station' syncs. The use of a digital frame store synchroniser enables the picture source (whether it be a single radio-camera or an entire OB scanner and a dozen cabled cameras) to run asynchronously with respect to station syncs, i.e. to operate with reference only to its own internally generated sync signal. Synchronisers are basically large digital memory arrays, where the incoming analogue video is digitised, written to memory, then read from that memory some time later, in a cyclic manner. By automatically delaying the incoming video by the appropriate amount, the signal output from the synchroniser is co-phased with the local video allowing proper sync cuts to be achieved.

Synchronisers are generally designed to carry reasonable quality signals and so can only deal with the small amounts of noise generated by a good quality link. They usually fail dramatically when presented with visible noise or short bursts of high level noise. The problem seems mainly due to the design of their sync separator, which is obviously a critical area when considering signals of variable quality.

Synchronisers used in studio technical areas need to lock-on to the incoming video signal very quickly, and must be able to respond to a sudden change of phase of input video when one source is exchanged for another. This type of sync separator must, therefore, have a short time constant to enable it

to adapt quickly. This switching of sources may occasionally be necessary for studio synchronisers, but those used for radio-camera applications are generally wired to the output of a single receiver for a considerable time — often for the duration of the entire race or game, although there are a few exceptions to this.

The technique of using a 'flywheel' sync separator is long established in domestic television receivers which need to be insensitive to noise spikes, and yet respond to sudden changes of the input signal when switching between TV channels. Broadcast equipment is generally less tolerant of noise; but when using mobile microwave links at a live OB, the picture quality can occasionally require more relaxed standards of operation.

2.1 Synchroniser fallback mode options

When the quality of the link deteriorates, and the video noise level rises, frame synchronisers usually give the option of going into one of several fallback modes as follows:

a) Bypass the synchroniser.

   This is not a feasible option because the timing delay, which is the reason for using a synchroniser, is then lost.

b) Cut to black level.

   This is a natural looking effect but is very annoying when it happens frequently. For severe loss, the synchroniser will completely cut to black giving no picture for long periods. This option is very occasionally used.

c) Freeze on the last 'good' picture.

   This option is most often selected because it presents a synchronised signal with as much picture information as possible. In practice, the last good picture which is held is usually far from acceptable. Again, this is very annoying if it happens repeatedly.

d) Garbage in, garbage out.

   Although this option may be claimed to be possible, in practice the synchronisers rarely perform as required and usually resort to freeze-framing.

In the freeze mode, loss of clean syncs causes the synchroniser to stop writing new video data to memory but to continue to read the contents; hence, a still picture is momentarily displayed until writing to the memory continues again. Unfortunately, even a small amount of visible noise can cause the synchroniser to freeze frame and this is often accompanied by loss of synchronisation. This causes the displayed picture to contain horizontally- and/or vertically-shifted blocks of picture information, even though the actual picture content of the blocks may be quite acceptable. This gives rise to such fragmented pictures as those shown in Figs. 1(a) and (b).

The effect of intermittent freeze-frame is rather annoying, especially if the problem, is repetitive, and can also give the impression that the event is recorded rather than being transmitted live. Synchroniser failure is usually impossible to predict, and the vision mixer is inclined to hang on to a particular shot for as long as possible (even though the pictures are breaking up), only to cut to another camera just as the link quality improves!

Whereas noise is a natural-looking degradation which the viewer is familiar with, synchroniser failure appears to be a less acceptable problem associated with play-back from a recording — in fact it is the random access memory of the synchroniser which is the storage medium in this case. Having gone to the expense of providing a live link, the last thing required is to give the impression that the event is recorded!

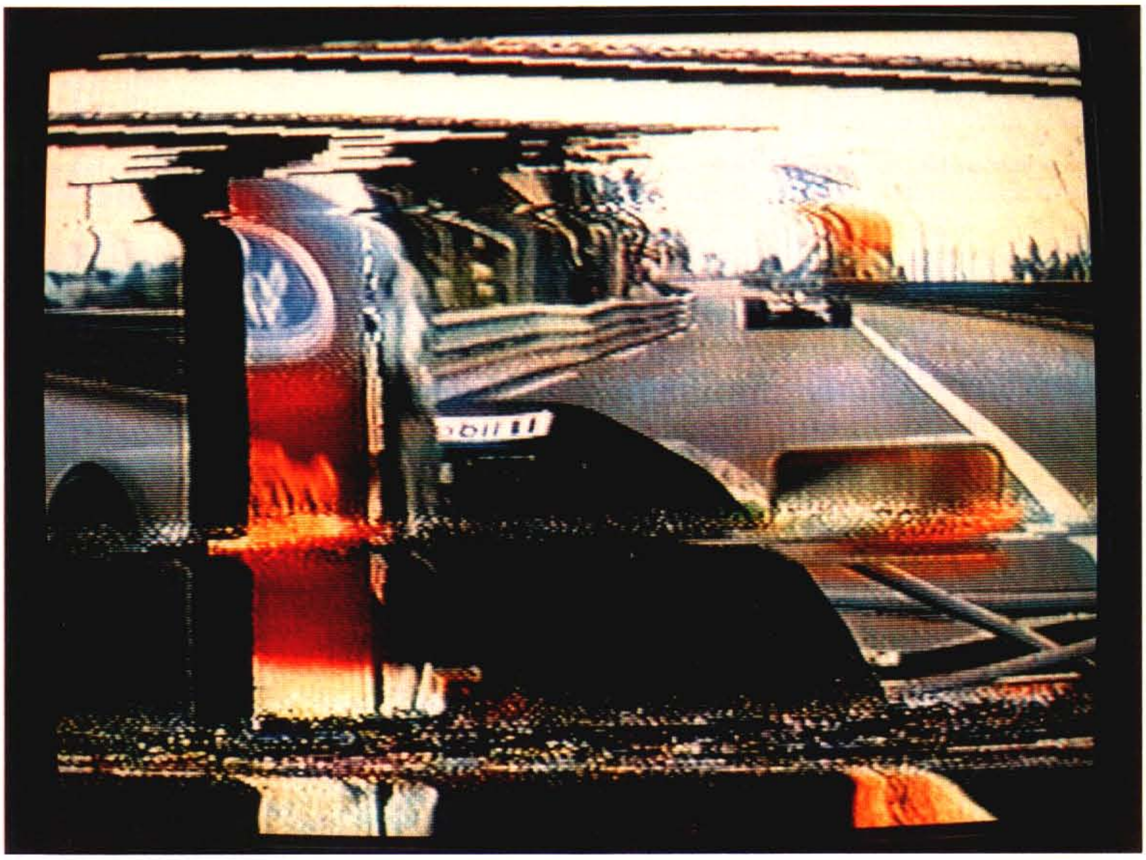
3. THE SOLUTION

While the active picture period of a video waveform is largely unpredictable, the synchronising components are completely predictable, and adhere to the appropriate specification — in the UK this being the PAL System I specification[2]. This allows considerable scope for replacing any sync information which may become distorted or lost due to momentary multipath distortion or high noise levels.

As can be seen from Fig. 2, RINSE uses a 'heavy flywheel action' sync separator to recover the timing information from the incoming video signal. The sync pulses can then continue to be generated, irrespective of the quality of the incoming signal. These flywheel syncs can be used to regenerate the full mixed sync pulse train, which is then substituted into the outgoing video signal in place of the video's own syncs. The resulting video is then considerably improved, and even for noisy signals, it can produce a well-timed but noisy video signal. By performing sync substitution, the performance of any digital video frame store synchroniser can be improved, as can be seen from Figs. 3(a) and (b).

The regeneration of mixed syncs using RINSE

(a) Single operator radio-camera at rugby match showing chrominance error, H-sync loss and V-sync loss.



(b) In-car camera at Formula 1 motor racing showing H-sync loss and tearing.

Fig. 1 - Off-air shots of synchroniser failure.

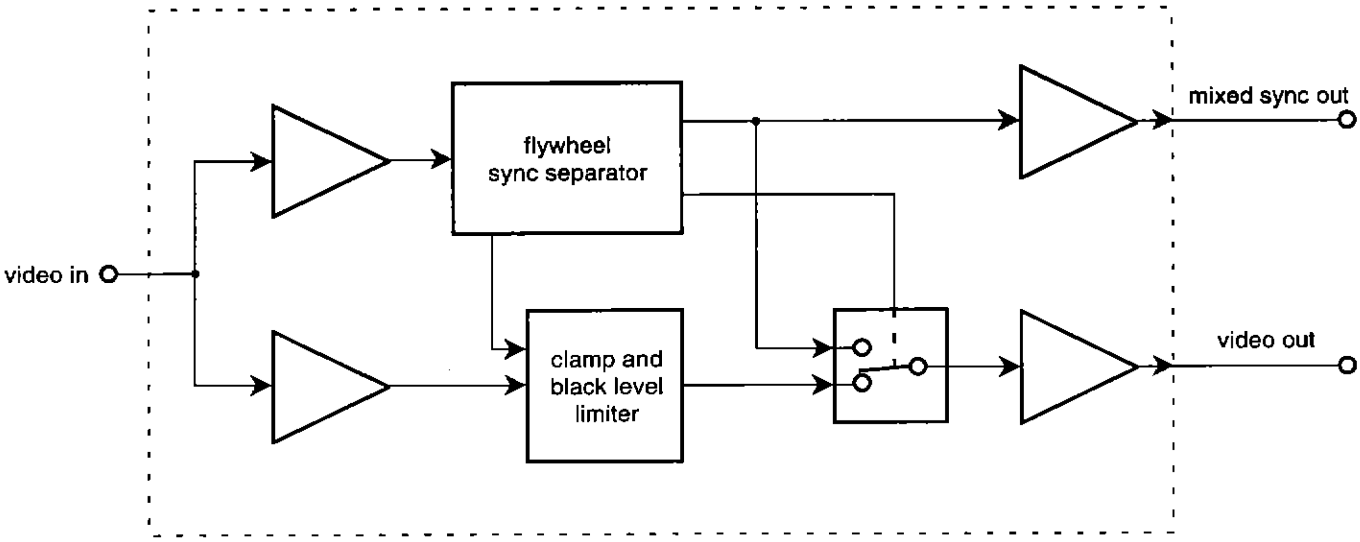


Fig. 2 - RINSE functional diagram.

produces several benefits. The consistent quality of the syncs means that:

1) Synchronisers are no longer the weak link in the video chain. The only effect of a noise spike on the synchroniser input is to produce a noise spike on the output picture. Freeze framing is greatly reduced and all degradation appears 'natural'. For a frame of mixed quality video, it ensures that the useful picture information is kept in its correct place on the screen.

2) Colour is maintained. By providing a reliable timing reference to identify the position of the burst, the correct colour can be maintained. Even though the colour burst may contain a large noise component, as long as the burst gate does sample the correct portion of the line, narrow band filtering allows it to be recovered.

Even in applications which do not use a video synchroniser, RINSE can often improve a noisy picture. Noisy video will cause small timing jitters in the sync separator of a picture monitor. The accurate timing of the sync pulses produced by RINSE means that the resulting picture is stable and does not suffer from tearing due to horizontal timing jitter, or frame roll when the vertical syncs are distorted or lost.

The effects of multipath propagation can be so severe that simply cleaning up the sync pulse train is insufficient. For severe link degradation, it is necessary to run the synchroniser via an external sync input. This requires a modification to the synchroniser circuitry (as an external sync reference for the *input* is not currently available on any commercial synchroniser). The most common type of synchroniser in use with BBC Tel OBs is very easily modified to accept external syncs when required, and this gives a huge increase in noise immunity.

RINSE is very effective at removing synchroniser artefacts due to noise and multipath propagation. However, it cannot reduce the actual noise level, and similarly it cannot correct the in-picture distortion, such as fluctuations in the chrominance, which are typical of multipath effects. What RINSE will do is to maintain a well-synchronised, stable picture.

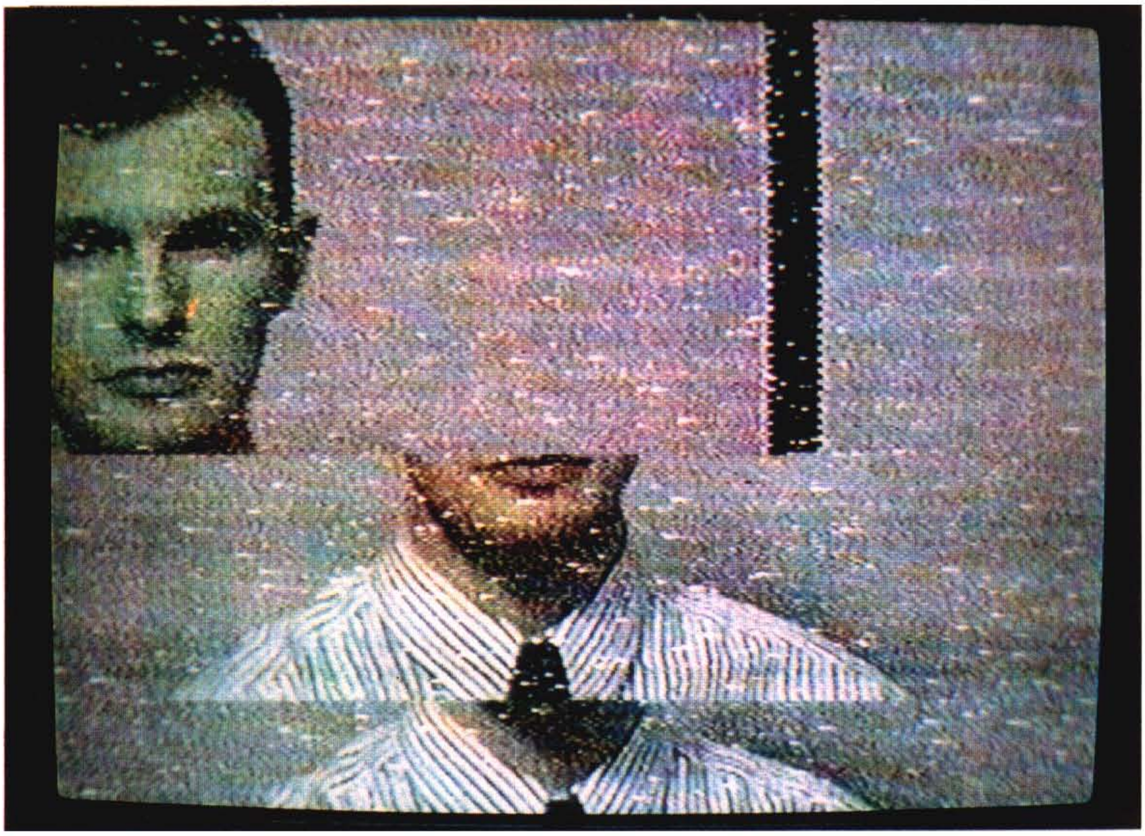
4. SYNCHRONISER NOISE PERFORMANCE

Within the BBC, approximately one-third of all synchronisers are dedicated to OB use, the others are used for synchronising the signals going into television studios/CAR* etc.

Of the synchronisers in use with Television Outside Broadcast Department, there are several different designs from a variety of manufacturers. Each type of synchroniser exhibits different properties when presented with variable quality video; but neither the price nor the age of the design seem to have much relevance when noise performance is considered.

Although manufacturers are able to quote good noise figures in terms of noise *distortion*, the quoted performance specifications usually lack any reference to sync separator noise performance figures, and manufacturers are usually reluctant to give details. To some extent this may be due to the difficulty in

* Central Apparatus Room.



(a) Severe noise causes synchroniser sync loss and freeze framing.

(b) Same level of noise but with RINSE connected in-line before the synchroniser.

Fig. 3 - Result of using RINSE with signal of high noise level.

specifying intermittent noise levels. Nevertheless, much equipment performs poorly when it is carrying noisy video.

Two typical video frame synchronisers were tested for sync separator noise immunity in the laboratory at Research Department. A 12.4 GHz transmitter, connected by heliax cable via a variable attenuator to the input of a receiver, allowed severe signal fading to be simulated in a constant environment.

In the tests, both frame synchronisers lost sync and produced intermittent freeze frame at about the same video noise level, −38 dB (weighted), when 'a few' noise spikes appeared on the input picture monitor (showing that the receiver is operating at or near threshold).

Although this noise level would not be sustained for very long periods on-air, there would obviously be many occasions when the signal level drops for a few seconds, and therefore the synchroniser should be able to pass the video transparently.

For both synchronisers, at the onset of freeze framing, RINSE was switched into circuit and this cured the problem completely, preventing freeze frame and allowing the synchronisers to pass the video. For more severe noise levels, simple sync re-insertion does not provide a complete cure. Gross distortion of the video signal during the active picture period can still cause problems with the synchroniser's sync separator. For completely accurate synchronisation, irrespective of the video noise level, the synchroniser must take its *input* video sync signal from an external input.

4.1 Impairment thresholds

It may be argued that video signals which are frequently impaired by signal loss are simply not used. In some cases this is true. Video which is *constantly* below a certain noise threshold will rarely be used on air. OB vision links are carefully planned to provide adequate signal level for normal conditions; therefore, constant noise is not a problem in an OB situation.

Unfortunately, at live OBs in an operational situation, there are many causes of momentary signal attenuation, such as helicopters banking, dish mis-panning, or simple obstructions such as trees or people getting in the way; but video with noise bursts lasting only a few frames is usually quite acceptable if the camera shots are exciting enough.

At a rugby match, a single operator radio-camera on the touch-line must provide a good signal, with virtually no link effects. Other camera shots are usually available from cabled cameras, and will be used in preference to an unreliable radio-linked camera.

In situations where the radio-linked camera is the only shot available, the acceptable quality threshold is reduced. This often occurs when facilities are stretched over a large area and there are few alternative options. For example, at the London Marathon the OB output contains a relatively high number of picture disturbances because of the use of car- or bike-mounted radio-cameras and the difficult environment they operate in. In these situations, some degradation is aceptable and does give the programme a 'live feel'.

The impairment to the viewer of video noise depends on both the duration and severity of the degradation. This can be broadly summarised in the graph of Fig. 4.

Although RINSE was developed primarily for OB type applications which use FM vision links, the techniques are equally applicable to satellite links which also use FM and operate at a similar frequency. The main difference in the channel characteristics between an OB mobile microwave link and a satellite link is the way the noise varies over time. An OB link is likely to be noise-free for most of the time, but may *suffer occasional bursts of severe noise when the direct* path is obstructed. A satellite link, on the other hand, is likely to suffer from a fixed noise level if the Carrier-to-Noise ratio (C/N) is insufficient, due to inadequate dish size, dish mis-alignment, or rain fading. RINSE copes very well with severe degradation lasting for a few seconds, but it will also 'clean up' less severe continuous noise.

In the world of news and current affairs, the acceptable threshold can be greatly reduced if the news story is important enough. With portable satellite link equipment becoming more widespread, the ability to use a lower quality link, and get that important news item, could be very useful. A better quality version could then be retransmitted at a more convenient time.

The microwave links, used by BBC Tel OBs for carrying video signals, use Frequency Modulation (FM) and during conditions of weak signal strength, this leads to 'threshold' noise which has a characteristic appearance. Whereas a weak AM link will produce a noise pattern with an even appearance, which gets more and more 'fuzzy' as the RF signal strength decreases, a weak FM signal will produce a spiky noise pattern. The number of spikes per frame increases as the RF level drops, until the picture information is lost in the noise. RINSE was designed

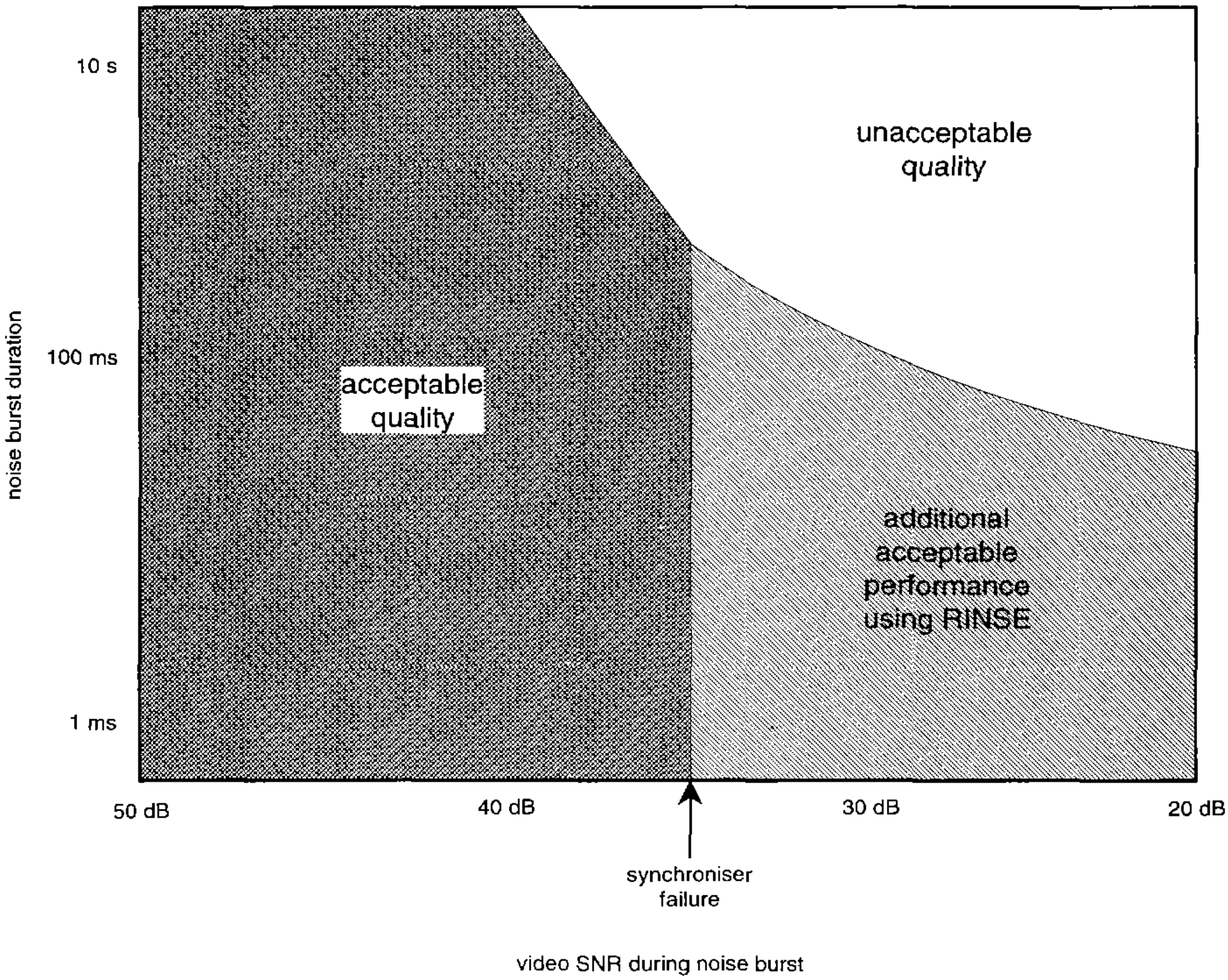


Fig. 4 - RINSE extends the acceptability threshold for noisy pictures.

to operate with this FM threshold-type noise. (It is threshold noise which causes the degradation in Fig. 2(b).)

5. THE DEVELOPMENT OF RINSE

Earlier work to provide a rugged noise-proof sync separator, for use with the switching radio-camera system[3], showed that by using a semi-digital approach, good noise immunity could be achieved.

Techniques such as dynamic windowing[4], to eliminate much of the noise and digital control of the VCO, means that the syncs could be made to flywheel accurately in the presence of severe noise or whenever there was a complete loss of the incoming video.

An initial experiment, during the 1992 London Marathon, showed that mixed syncs which were *regenerated* from a source in this way could *maximise the picture information* in cases of variable signal quality.

From the concepts used in the initial radio-camera sync separator, and from the results of the tests during the 1992 London Marathon, RINSE was created to fully regenerate the video syncs and then re-insert them into the outgoing signal.

6. HOW IT WORKS

Standard flywheel sync separators generally incorporate an on-board variable frequency oscillator (VFO) and a phase locked loop (PLL). The PLL adjusts both the frequency and also, therefore, the phase of the VFO, to match the incoming signal. RINSE adjusts each parameter separately. The frequency of the VFO — actually a Voltage Controlled Crystal Oscillator or VCXO — is measured using a frequency comparator and then

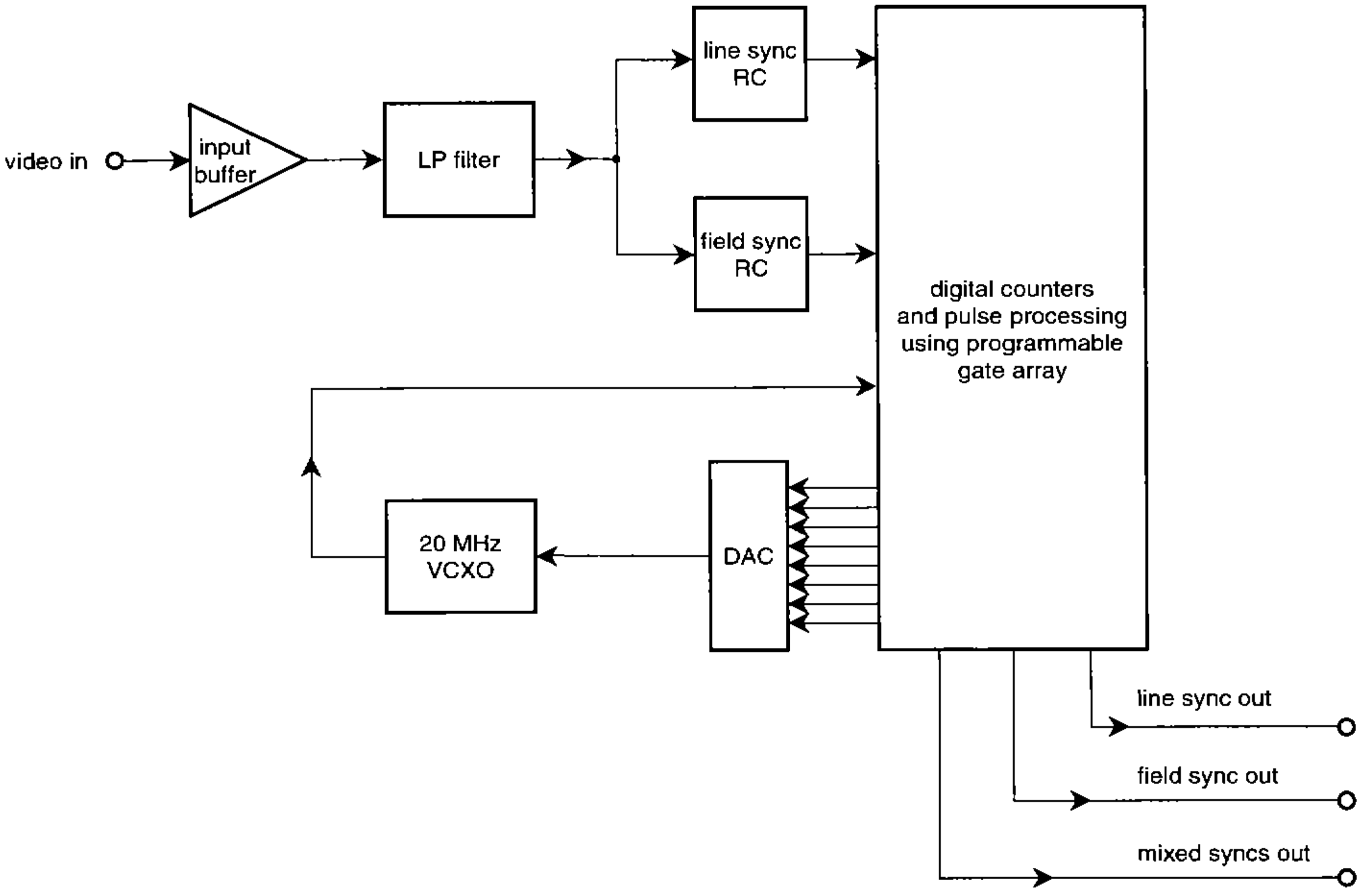


Fig. 5 - The basic sync separator block diagram.

adjusted. The phase of the output signal is corrected by resetting digital counters. In this way, correct phase can be established virtually independently of frequency. The VCXO is not controlled by the voltage held on a capacitor but by a DAC, as shown in Fig. 5. The digital approach means that, unlike a capacitor, the control voltage wil not decay when held, and can be instantly pre-set to any level.

An adaptive windowing system allows the counters to be reset by only genuine incoming syncs, and rejects mistimed pulses caused by noise. Once the incoming and outgoing syncs are approximately in phase, a frequency-locked loop adjusts the frequency of the VCXO so that the outgoing syncs are running at the same rate as the incoming video signal. The use of digital counters means that instantaneous phase changes are possible. Because the phase of both the line syncs and the field syncs is adjusted in this way, the frequency does not need to be able to swing over a large range. In fact, the VCXO used in RINSE only needs to cater for the frequency inaccuracy of the source, which should rarely be more than ± 1 p.p.m. for a full broadcast-quality camera. RINSE requires a greater frequency-tracking ability (e.g. ± 15 p.p.m.) when used with the increasingly-popular miniature cameras.

Using a 20 MHz VCXO, the sync pulses are generated to a resolution of 50 ns, as is required by the PAL System I specification. However, because the phase of the master VCXO is asynchronous with respect to the timing of the sync edges of the incoming video signal, there will be a small varying error between the regenerated syncs and the incoming syncs. Although this jitter is small, it is disturbing to the eye if the regenerated syncs are related to the picture in any visual way (i.e. if sync substitution is carried out or if a picture monitor is fed with these jittery syncs). The jitter can be removed by the introduction of a standard phase locked loop, with a suitable low pass filter in the feedback path to a second VCXO. The PLL averages out the phase error between the regenerated syncs and the PLL syncs. It is this second VCO which provides the clock for the counters which produce the final output sync pulses.

6.1 Dynamic windowing

Most advanced designs of sync separator use a timing window to prevent spurious triggering by noise pulses during the periods when a genuine line sync pulse should not occur. This effectively means opening a window about 63 μs after the last line sync pulse, and closing it again 1 μs after the next sync

pulse. RINSE goes further than this and uses *dynamic* windowing, where the size of the window depends on the quality of the video signal. The apparent position of the line sync edge is effected by the noise in the sync pulse; therefore, an adaptive window is used to extract the timing information. For noisy syncs, the exact position of the reference (i.e. negative-going) sync edge cannot accurately be determined and so a relatively wide window is used to allow the pulse through. For near-studio quality signals, however, the edge will be well defined and so a very small 100 ns window is applied. The windowing control circuitry varies the size of the window symmetrically about the line sync edge to suit the noise level.

The dynamic windowing circuitry provides a measure of the noise level, prevents spurious triggering, and locks on to the correct phase very quickly.

Having regenerated the syncs, these are clamped to the same level as the video signal and then multiplexed in. During the field blanking interval, the whole of the field blanking interval and surrounding lines are replaced.

6.2 Flywheeling

RINSE has some simple immunity to low levels of noise, but also a sophisticated flywheeling system to carry it through periods of severe noise. It switches between its tracking and its flywheeling modes automatically to try to maintain the quality of its output syncs.

RINSE operates in its *tracking mode* under normal conditions of clean signal, where it adjusts its reference oscillator to match the frequency of the incoming syncs. If an established clean video signal then becomes gradually degraded, RINSE will track the signal into the noise until it is forced to flywheel by the uncertainty of the sync edge positions.

However, if a clean signal suddenly becomes very noisy, then it will detect this sudden change and start a flywheel sequence, in which it ignores the incoming video signal for a pre-set time. This pre-set flywheel time can be set according to the expected duration of the degradation. At the end of the pre-set flywheeling period, it tries to correct any error and re-acquire lock. If the signal is still very poor it may start another pre-set flywheel sequence; however, if flywheeling continues for a long time then the small frequency inaccuracy between the incoming video signal and the outgoing syncs will eventually become evident and the clamping and the sync pulses will be generated in the wrong position relative to the picture. If flywheeling is not required, it can be disabled and RINSE will then try to track the signal continuously.

7. THE LIMITATIONS OF RINSE

The concept of RINSE is one of constancy and stability. Once locked-on to the incoming video signal, it provides a reliable sync train, even in the complete absence of video; and its lack of response to sudden variations in the input signal gives it good noise immunity. However, this constancy also means that RINSE is only suitable for cleaning up video of constant frequency and phase. If it is used in a situation where the input signal is being switched between two or more free-running cameras then a problem arises. In this situation, RINSE will hold on to the phase and frequency of the old video signal until the new video has had enough influence for RINSE to readjust. This readjustment will take a few seconds, the exact time being governed by the phase and frequency difference between the old and the new video signals.

These asynchronous 'hot' cuts are not used on air, so a RINSE unit which only re-inserts new syncs when it is confident of being locked to video, would not create this problem. On detection of a new source, it would simply pass the incoming video transparently until the flywheel sync separator was confident that its syncs were correctly timed.

RINSE was designed to provide consistent quality syncs during relatively short periods of signal degradation such as may occur during live radio-camera operation. Its good noise immunity allows it to work with noise levels beyond the limit of acceptability. However, *constantly*-noisy video signals can produce a problem, in that there are no definite sync edges to lock to; in these circumstances, its performance is not as good. With this type of situation, the exact severity of the noise is important and RINSE can only be tried out to see how much benefit it can provide.

Another of the design specifications was that the input syncs would be generated electronically and therefore would be relatively stable. The signals obtained from a video tape recorder with no time base correction would not be regular enough for RINSE; so it is not suitable for recovering material from damaged tape for instance. However, when an off-tape signal, which is then time base corrected, is transmitted through a low quality RF channel, RINSE will clean it up very effectively.

8. RINSE IN USE

Because RINSE provides two types of output signal, it can be used in two possible ways. The mixed syncs derived from the input video signal are available for connecting to other equipment, while the video

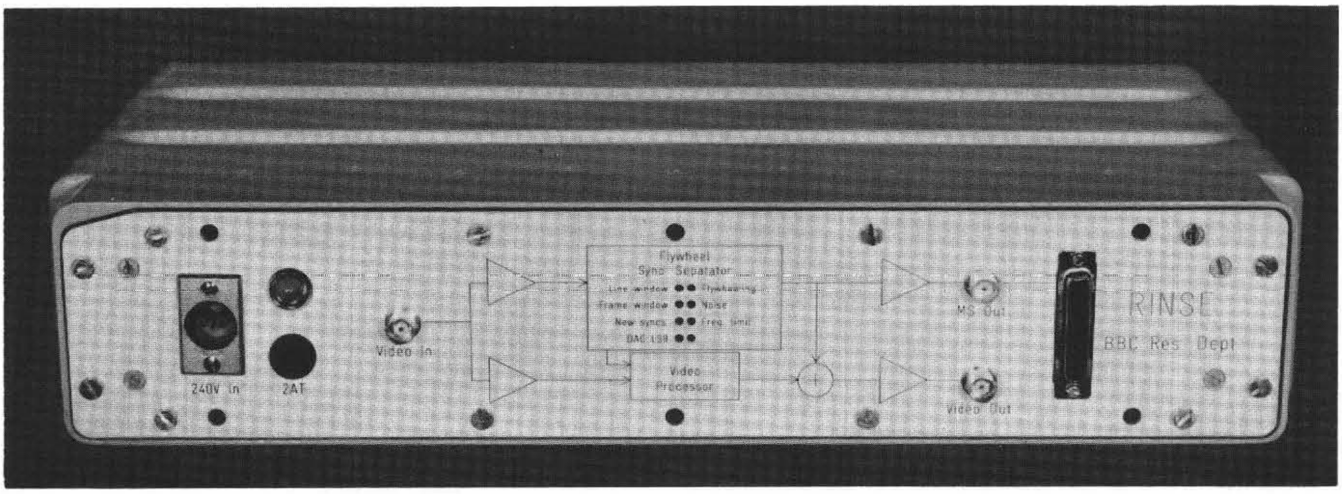


Fig. 6 - The prototype single channel RINSE unit in its rugged 'OB proof' case.

output of RINSE contains variable-quality picture material with steady syncs. The prototype RINSE unit is shown in Fig. 6.

For synchroniser use, the RINSE unit is connected in the video path between the link/satellite receiver's video output and the synchroniser's video input so that it can substitute clean syncs. There is no advantage in using the RINSE unit after the frame synchroniser, because by then, the 'damage' has been done. As a means for cleaning up video, the video signal with clean syncs output can be piped into the next piece of equipment.

Having switched on the RINSE unit and presented it with a clean video signal, it takes a few seconds for the PLL to settle. RINSE simultaneously adjusts its internal oscillator to match the frequency of the incoming line syncs. As it adjusts its frequency, it shifts the picture horizontally. The horizontal shifts will get smaller and smaller until the frequency is as close as it will get. At some time during all this, the vertical syncs will lock-in and the picture will settle.

The exact time taken to lock is determined by:

a) The difference between the line frequency of the incoming video signal and the initial line frequency of RINSE.

b) The difference in the line phases of the incoming and regenerated syncs.

c) The noise level of the video signal.

d) The use of the manual 'fast-lock' switch.

Typically, RINSE takes about 10 - 20 seconds from switch-on to full lock, although it is quite obvious when it has actually achieved this. At switch-on RINSE assumes the incoming line frequency will be 15,625.00 Hz and pre-sets its internal oscillator to this frequency. In the case of well designed and maintained equipment, RINSE will therefore not need to adjust itself to any great degree, so the lock-up time wil be very quick. However, badly aligned equipment which generates an inaccurate line frequency, will take longer to lock to, so RINSE has a manual intervention mode which can speed up the frequency-matching process if required.

9. CONCLUSIONS

The BBC often uses video synchronisers in its programme chain. For most applications, standard commercial synchronisers perform well enough, but when used with mobile microwave links they can often cause additional signal degradation, rendering a slightly noisy signal completely unusable.

By performing sync substitution using RINSE, the noise performance of any video frame synchroniser can be improved, with no internal modification being required to the synchroniser. However, for the best possible results, the synchroniser should operate via an external sync input which requires a simple modification.

RINSE effectively extends the operational area of radio-cameras. Momentary signal losses, for whatever reason, can now be smoothed over with remarkable results. This applies to full specification broadcast cameras and also to miniature 'lipstick' cameras.

The regeneration of mixed syncs using RINSE produces several benefits. The consistent quality of the syncs means that:

1) Synchronisers are no longer the weak link in the video chain. The only effect of a noise

spike on the synchroniser input is to produce a noise spike on the output picture. Freeze-framing is greatly reduced and all degradation appears natural. For a frame of mixed quality video it ensures that the useful picture information is kept in its correct place on the screen.

2) Colour is maintained. By providing a reliable timing reference to identify the position of the burst, the correct colour can be maintained.

The use of video synchronisers with mobile radio-cameras has often led to an unnecessary further degradation of the signal, characterised by sync loss and freeze-framing. These effects have generally been attributed to the antennas and RF link equipment which carries the video signal. However, using RINSE it is possible to dramatically improve the link quality and completely eliminate synchroniser artefacts.

10. RECOMMENDATION

One method of improving the performance of future synchronisers would be to incorporate a RINSE-type flywheel sync separator within the synchroniser. However, a simpler option would be to *incorporate an optional external sync input into future* synchroniser designs or versions in a similar manner to the 'internal/external sync' switch of a picture monitor. This small modification would allow RINSE-type devices to considerably enhance synchroniser performance at little extra expense to the synchroniser manufacturers.

11. ACKNOWLEDGEMENTS

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